Improved Passive Precipitation Retrievals over Snow-covered Surfaces and Coastal Zones

Ardeshir Ebtehaj [a] , Efi Foufoula Georgiou [b] , and Rafael L Bras [c]

[a] University of Minnesota, [b] University of California Irvine ; [c] Georgia Institute of Technology

Goal and Motivation

- To better understand microwave radiometric signatures of precipitation (rainfall and snowfall) over radiometrically complex land surfaces. The objective is to design a new land-atmosphere retrieval method for:

1) improving the quality of precipitation retrievals over snow-covered land surfaces and coastal areas.
2) improving the quality of orographic precipitation retrievals, especially snowfall over snow-covered high-mountain areas.
3) obtaining state-of-the-art results not only for precipitation retrievals but also for retrievals of land surface state variables and parameters such as snow-cover physical properties and inundation—using GMI data.

A Land-Atmosphere Retrieval Framework

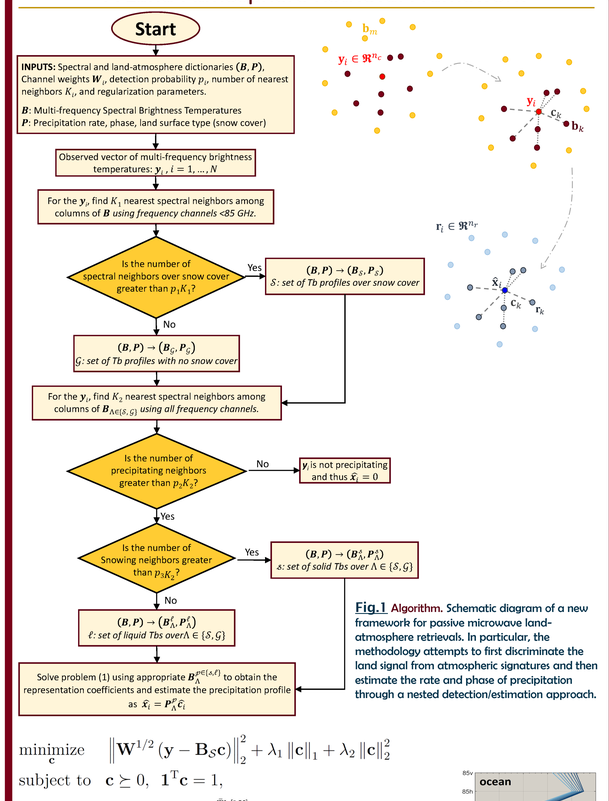

Fig.1 Algorithm. Schematic diagram of a new framework for passive microwave land-atmosphere retrieval. In particular, the methodology attempts to first discriminate the land signal from atmospheric signatures and then estimate the rate and phase of precipitation through a nested detection/estimation approach.

$$\underset{\mathbf{c}}{\text{minimize}} \quad \left\|\mathbf{W}^{1/2}\left(\mathbf{y}-\mathbf{B}_{\mathcal{S}}\mathbf{c}\right)\right\|_2^2+\lambda_1\left\|\mathbf{c}\right\|_1+\lambda_2\left\|\mathbf{c}\right\|_2^2$$

$$\text{subject to} \quad \mathbf{c}\succeq 0,\ \ \mathbf{1}^{\mathrm{T}}\mathbf{c}=1,$$

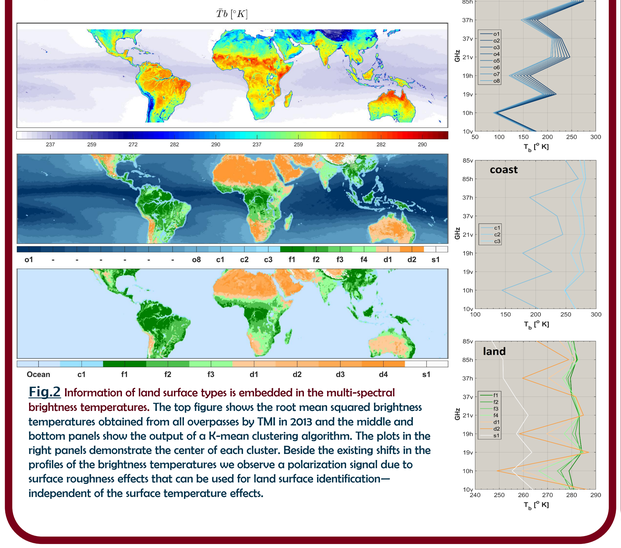

Fig.2 Information of land surface types is embedded in the multi-spectral brightness temperatures. The top figure shows the root mean squared brightness temperatures obtained from all overpasses by TMI in 2013 and the middle and bottom panels show the output of a K-mean clustering algorithm. The plots in the right panels demonstrate the center of each cluster. Beside the existing shifts in the profiles of the brightness temperatures we observe a polarization signal due to surface roughness effects that can be used for land surface identification—independent of the surface temperature effects.

ShARP Precipitation Phase Detection in GPM Era

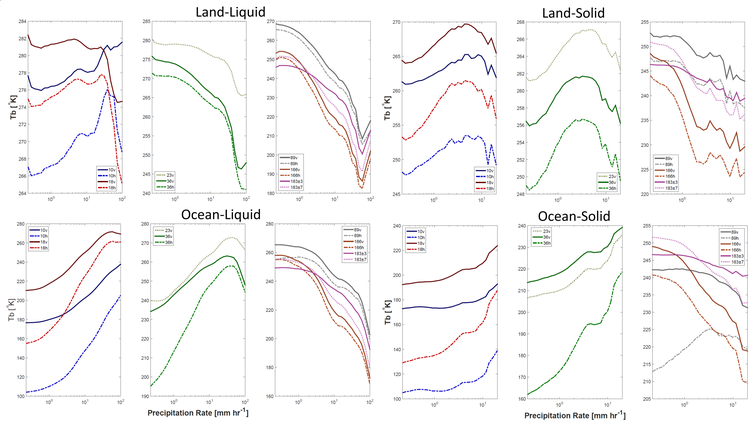

Fig.3 GMI spectral response to precipitation rate over ocean and land for solid and liquid phases of precipitation.

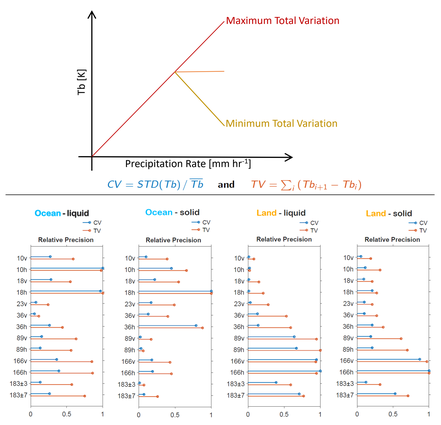

Fig.4 GMI spectral weights using total variation of channel response.

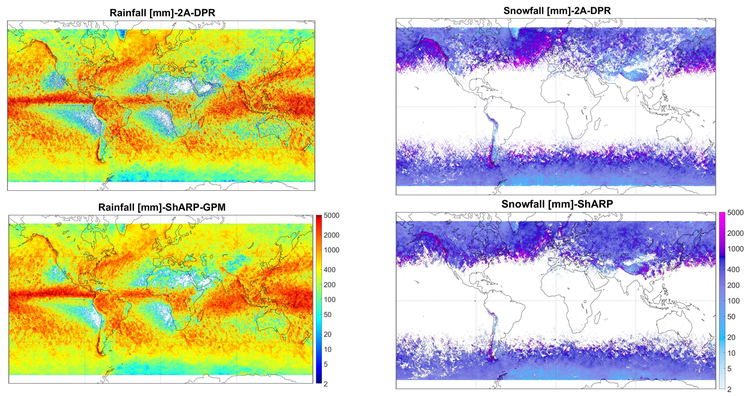

Fig.5 ShARP passive precipitation (left and snowfall retrievals versus 2A-DPR active precipitation retrievals.

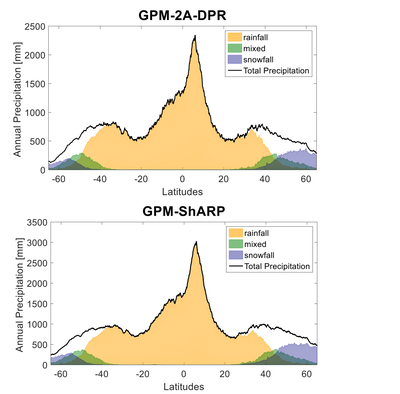

Fig.6 Latitudinal average of the retrievals and precipitation phases

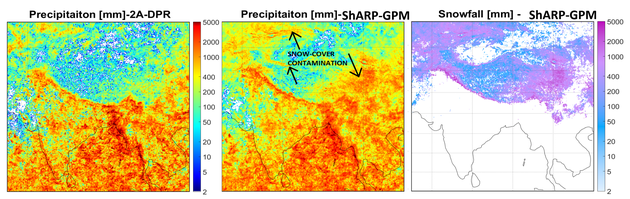

Fig.7 ShARP passive precipitation and snowfall retrievals versus 2A-DPR active precipitation retrievals over Himalayas for winter overpasses. Snow-cover contamination is an important issue.

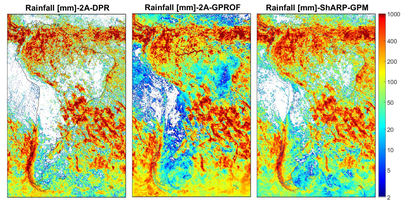

Fig.8 ShARP passive precipitation retrievals versus 2A-GPROF and 2A-DPR active precipitation retrievals for all overpasses in 2015. Improved retrievals over coastal areas are apparent.

What we are doing now!

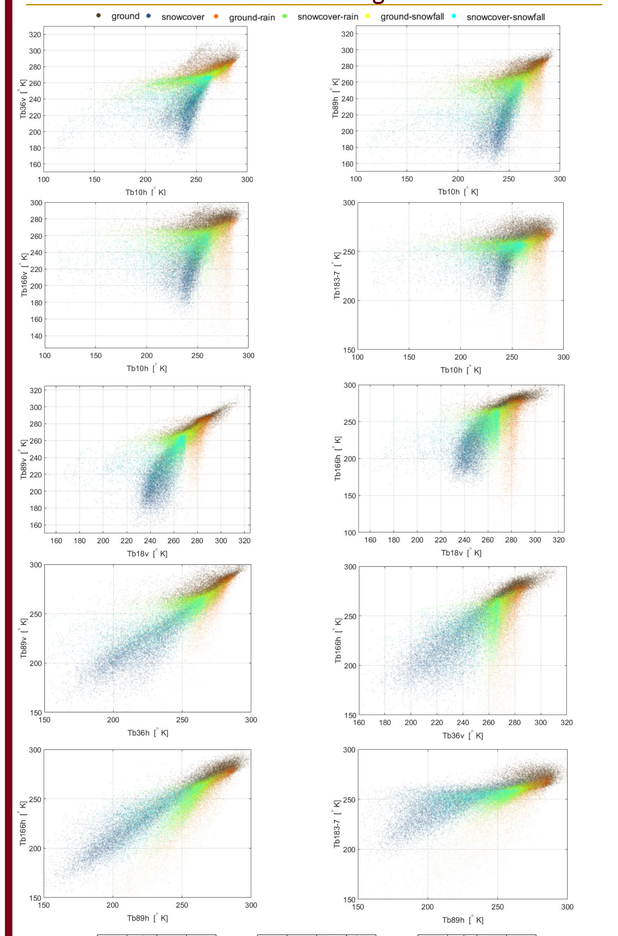

Fig.10 Global GMI multi-frequency response to snow-cover, rainfall and snowfall. Both rainfall and snowfall exhibit warming signatures snow cover. The data are obtained form more than 30 million samples over land.

ShARP: Snowfall over complex Land Surfaces (coastal areas, snow-covered lands)

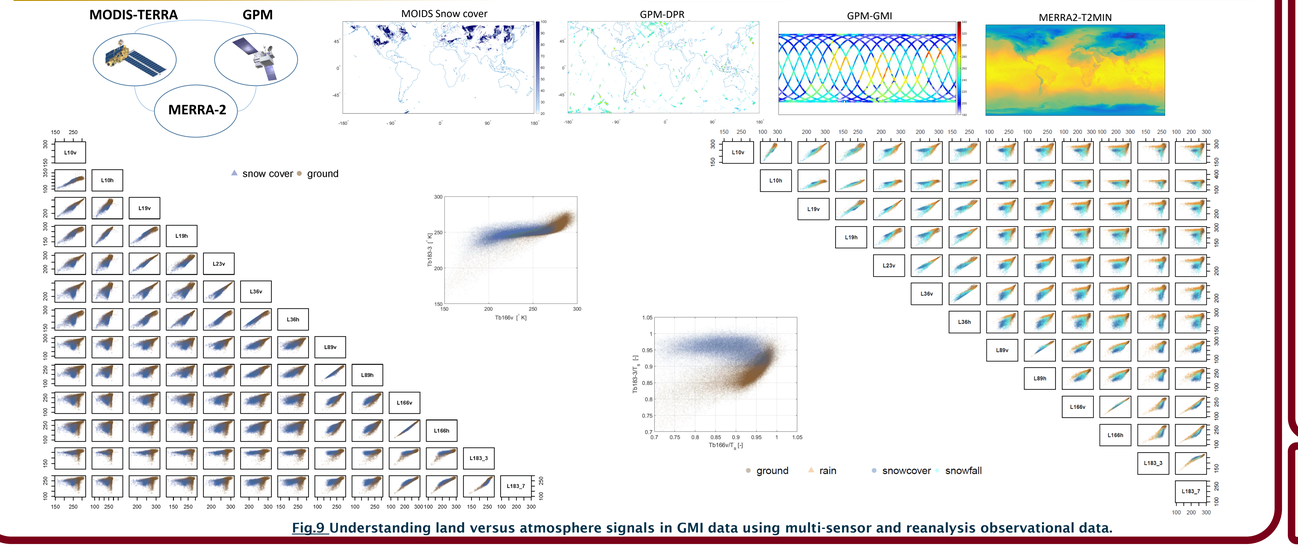

Fig.9 Understanding land versus atmosphere signals in GMI data using multi-sensor and reanalysis observational data.

- Land surface types (e.g., snow-cover) and precipitation physical properties (e.g., phase) are distinguishable to some extent in microwave bands using GMI data.
- New high-frequency channels provide extra and critical information for proper discrimination of precipitation phase change especially in 166 and 183-7 GHz.
- A new method is being explored to estimate the inverse of channels' error covariance to obtain different similarity matrices for improved discrimination of different land surface types from the atmospheric signals.

$$\underset{\mathbf{R}}{\text{minimize}} \sum_{i,\,j}\left(\mathbf{x}_i-\mathbf{x}_j\right)^T\mathbf{R}\left(\mathbf{x}_i-\mathbf{x}_j\right)$$

$$\text{subject to } \mathbf{R}\succeq 0$$

Acknowledgment: This research is supported by two GPM grants NNX13AG33G, NNX13AH35G, NNX16AO56G.

1- Ebtehaj, A.M., R.L. Bras, E. Foufoula-Georgiou (2015), "Shrunken locally linear embedding for passive microwave retrieval of precipitation", *IEEE Trans. on Geosci. and Remote Sens.*, vol 53(7), doi:10.1109/TGRS.2014.2382436.

2- Ebtehaj, A.M., R.L. Bras, E. Foufoula-Georgiou (2016), "Evaluation of ShARP passive rainfall retrievals over snow-covered land surfaces and coastal zones", *J. Hydrometeor,* 17, 1013–1029.doi:doi: http://dx.doi.org/10.1175/JHM-D-15-0164.1

3- Takbiri Z. , A. M. Ebtehaj, E. Foufoula-Georgiou (2016), "A Bayesian Approach for all-sky Passive Microwave Inundation Retrievals", *J. Hydrology and Earth Sys. Science*, under review.